tau decay systematic: powheg-pythia vs powheg-tauola

Introduction

- We have two powheg ttbar samples, which we think are the same except for tau decay: one uses pythia, the other uses tauola. Pythia ignores the tau polarisation when simulating the decay, while tauola treats it correctly.
  - **TTTo2L2Nu2B_7TeV-powheg-pythia6**
  - **TT_TuneZ2_7TeV-powheg-tauola**
- Two parts of the asymmetry analysis are dependent on the ttbar->dileptons MC:
  - Acceptance matrix
  - Migration matrix
- The difference between the measured asymmetries when using powheg-pythia and powheg-tauola for these matrices should give the systematic associated with the mismodeling of the tau decays in powheg-pythia (next slide)

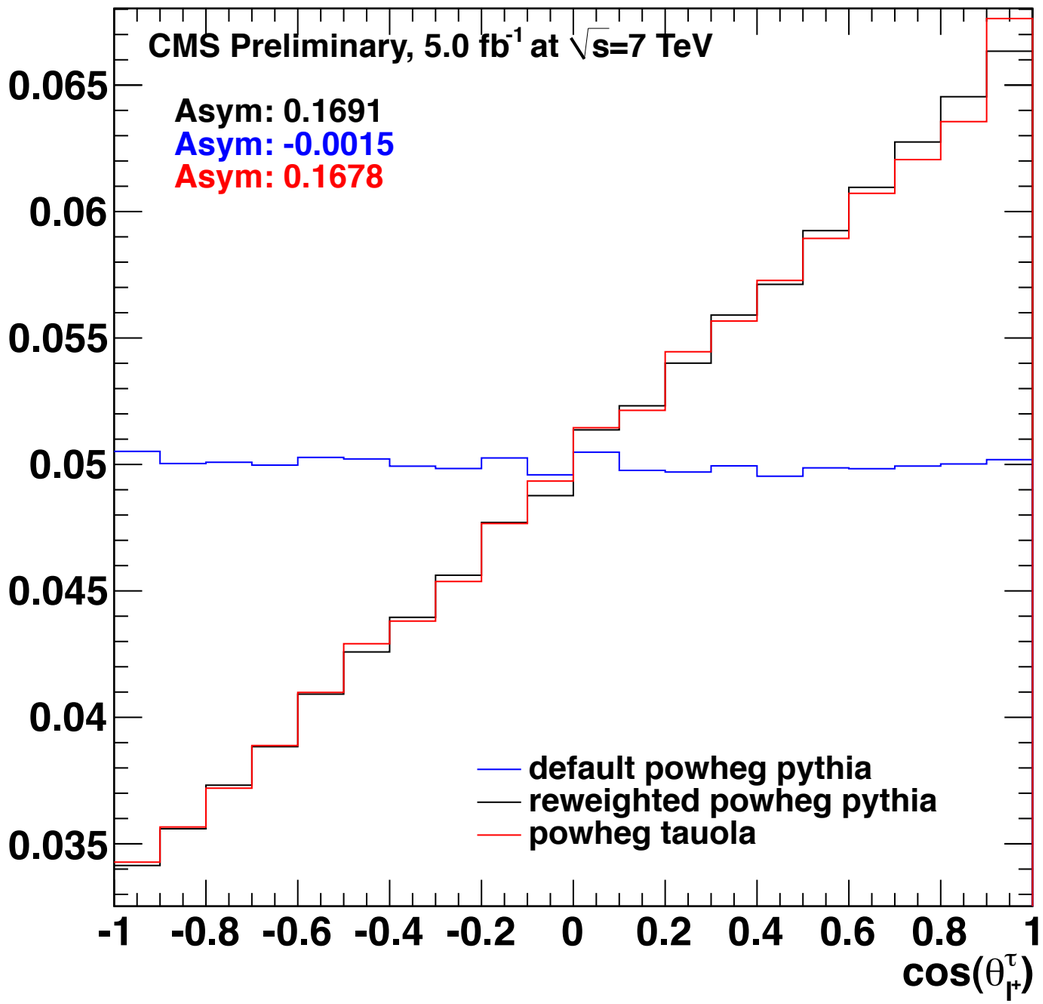
Results (powheg-pythia vs powheg-tauola)

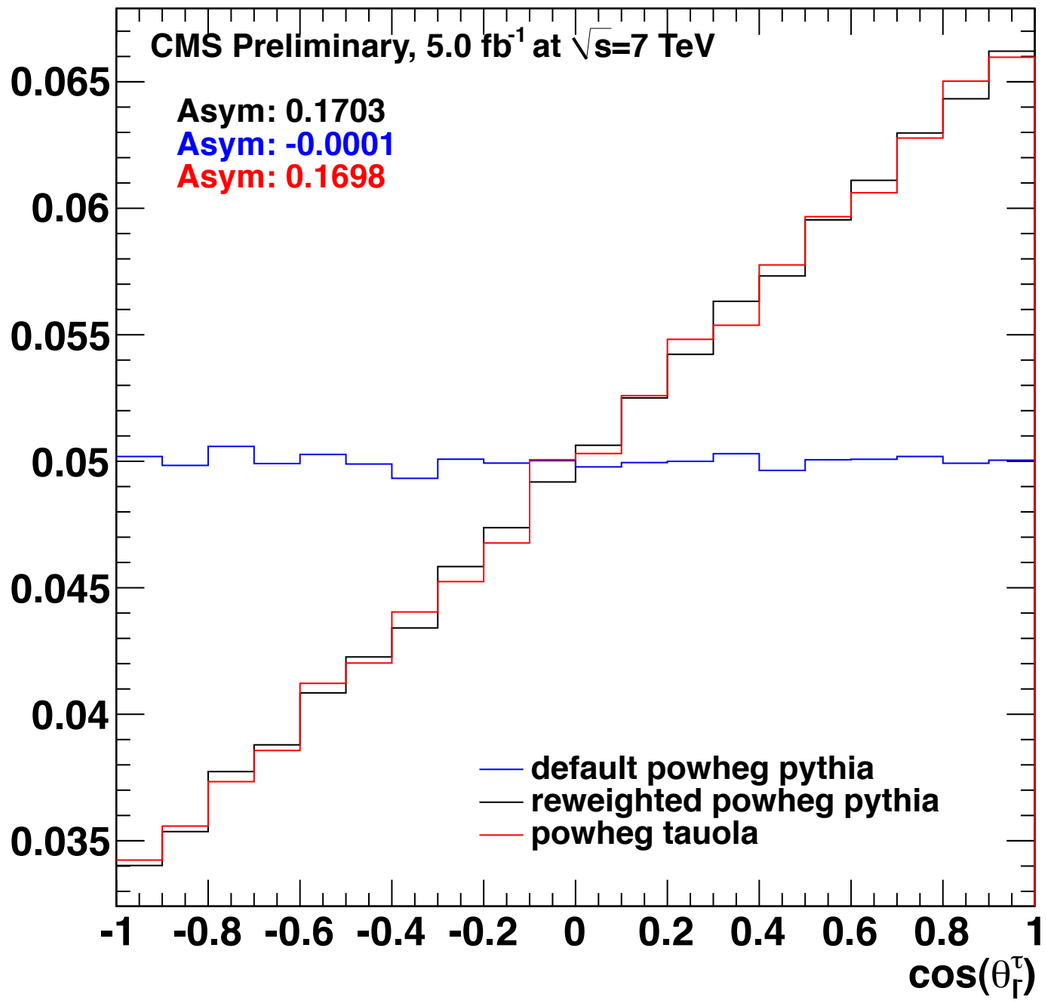
	powheg-pythia results (same as in PAS)	powheg-tauola results	difference	difference (changing acceptance matrix only)
$\mathcal{A}^{\ell\ell}_{\Delta\phi} = \frac{N(\cos\Delta\phi_{\ell\ell} > 0) - N(\cos\Delta\phi_{\ell\ell} < 0)}{N(\cos\Delta\phi_{\ell\ell} > 0) + N(\cos\Delta\phi_{\ell\ell} < 0)}$	-0.097	-0.094	0.0037	0.0039
$\mathcal{P}_n^{+} = \frac{N(\cos\theta_{\ell,n} > 0) - N(\cos\theta_{\ell,n} < 0))}{N(\cos\theta_{\ell,n} > 0) + N(\cos\theta_{\ell,n} < 0))}$	-0.035	-0.024	0.0105	0.0034
$\mathcal{P}_n^{-} = \frac{N(\cos\theta_{\ell,n} > 0) - N(\cos\theta_{\ell,n} < 0))}{N(\cos\theta_{\ell,n} > 0) + N(\cos\theta_{\ell,n} < 0))}$	0.019	0.034	0.0148	0.0012
$\mathcal{A}^{\ell}_{c_1c_2} = \frac{N(c_1c_2 > 0) - N(c_1c_2 < 0))}{N(c_1c_2 > 0) + N(c_1c_2 < 0))}$	-0.015	-0.008	0.0070	0.0039
$A_{lepC} = \frac{N(\lvert\eta_{l^+}\rvert > \lvert\eta_{l^-}\rvert) - N(\lvert\eta_{l^+}\rvert < \lvert\eta_{l^-}\rvert)}{N(\lvert\eta_{l^+}\rvert > \lvert\eta_{l^-}\rvert) + N(\lvert\eta_{l^+}\rvert < \lvert\eta_{l^-}\rvert)}$	0.010	0.010	0.0002	0.0032
$A_{topFB} = \frac{N(\cos(\theta_t) > 0) - N(\cos(\theta_t) < 0)}{N(\cos(\theta_t) > 0) + N(\cos(\theta_t) < 0)}$	-0.011	-0.017	-0.0063	0.0012

- Biggest shift seen in top polarisation. Consistent results in independent + and - lepton samples: shift = ~0.013.
- Difference in measured polarisation comes mostly from difference in migration matrices
- Difference in lepton azimuthal asymmetry mostly due to difference in acceptance matrices
  - but could be mostly statistical (including stat uncertainty the result is 0.0039 ± 0.0025)

powheg-pythia reweighting

- Try reweighting angular distribution of tau decays in powheg-pythia to reproduce the effect
- Distribution is given by $\frac{d\Gamma(l^{\pm})}{d\Omega dx} = \frac{G^2 m_l^5}{192\pi^4} x^2 \{3(1-x) + \frac{2}{3}\rho(4x-3) + 6\eta\frac{m_e}{m_l}\frac{1-x}{x} \pm \xi P_l \cos\theta[1-x+\frac{2}{3}\delta(4x-3)]\}$
- Weight events by 1 + (P Cosθ (2 *x* - 1))/(3 - 2 *x*) where *x* = (lepton momentum)/(max possible lepton momentum) and θ = (angle of daughter lepton in tau rest frame)
  - also reweight *x* distribution to match that of powheg-tauola (this effect is small)





- Powheg pythia distribution looks like powheg-tauola distribution after reweighting

- Weighted results show much smaller systematic shifts than powheg-tauola vs powheg pythia (am I missing some other difference between these MCs?)
  - also tried simple weighting (ignoring *x* dependence), just 1 + (P Cosθ)/3 , and found similar results
- The largest shift is still seen in top polarisation, and again consistent results are seen between + and - leptons
- Top spin correlation (A_{c1c2}) shifts in the opposite direction than on slide 3

	powheg-pythia results (same as in PAS)	**reweighted powheg-pythia results**	**difference**	**difference (changing acceptance matrix only)**
$\mathcal{A}^{\ell\ell}_{\Delta\phi} = \frac{N(\cos\Delta\phi_{\ell\ell} > 0) - N(\cos\Delta\phi_{\ell\ell} < 0)}{N(\cos\Delta\phi_{\ell\ell} > 0) + N(\cos\Delta\phi_{\ell\ell} < 0)}$	-0.097	-0.097	0.0004	0.0004
$\mathcal{P}^{+}_{n} = \frac{N(\cos\theta_{\ell,n} > 0) - N(\cos\theta_{\ell,n} < 0))}{N(\cos\theta_{\ell,n} > 0) + N(\cos\theta_{\ell,n} < 0))}$	-0.035	-0.033	0.0019	-0.0005
$\mathcal{P}^{-}_{n} = \frac{N(\cos\theta_{\ell,n} > 0) - N(\cos\theta_{\ell,n} < 0))}{N(\cos\theta_{\ell,n} > 0) + N(\cos\theta_{\ell,n} < 0))}$	0.019	0.021	0.0023	-0.0004
$\mathcal{A}^{\ell}_{c_1c_2} = \frac{N(c_1c_2 > 0) - N(c_1c_2 < 0))}{N(c_1c_2 > 0) + N(c_1c_2 < 0))}$	-0.015	-0.015	-0.0007	0.0000
$A_{lepC} = \frac{N(\lvert\eta_{l^+}\rvert > \lvert\eta_{l^-}\rvert) - N(\lvert\eta_{l^+}\rvert < \lvert\eta_{l^-}\rvert)}{N(\lvert\eta_{l^+}\rvert > \lvert\eta_{l^-}\rvert) + N(\lvert\eta_{l^+}\rvert < \lvert\eta_{l^-}\rvert)}$	0.010	0.010	-0.0000	-0.0001
$A_{topFB} = \frac{N(\cos(\theta_t) > 0) - N(\cos(\theta_t) < 0)}{N(\cos(\theta_t) > 0) + N(\cos(\theta_t) < 0)}$	-0.011	-0.011	0.0000	0.0002

check for other differences between the two MC

- If the only difference was in the tau decay, we would see compatible results between the two MCs when excluding events with taus from the acceptance matrix and the smearing matrix
- Results below: actually most of the difference between the two MCs is independent of taus!

	powheg-pythia results (no taus)	**powheg-tauola results (no taus)**	**difference**	**difference attributable to tau decay**
$\mathcal{A}^{\ell\ell}_{\Delta\phi} = \frac{N(\cos\Delta\phi_{\ell\ell} > 0) - N(\cos\Delta\phi_{\ell\ell} < 0)}{N(\cos\Delta\phi_{\ell\ell} > 0) + N(\cos\Delta\phi_{\ell\ell} < 0)}$	-0.112	-0.107	0.0043	-0.0006
$\mathcal{P}^{+}_{n} = \frac{N(\cos\theta_{\ell,n} > 0) - N(\cos\theta_{\ell,n} < 0))}{N(\cos\theta_{\ell,n} > 0) + N(\cos\theta_{\ell,n} < 0))}$	-0.065	-0.059	0.0063	0.0042
$\mathcal{P}^{-}_{n} = \frac{N(\cos\theta_{\ell,n} > 0) - N(\cos\theta_{\ell,n} < 0))}{N(\cos\theta_{\ell,n} > 0) + N(\cos\theta_{\ell,n} < 0))}$	-0.015	-0.003	0.0123	0.0025
$\mathcal{A}^{\ell}_{c_1c_2} = \frac{N(c_1c_2 > 0) - N(c_1c_2 < 0))}{N(c_1c_2 > 0) + N(c_1c_2 < 0))}$	-0.003	0.008	0.0111	-0.0042
$A_{lepC} = \frac{N(\lvert\eta_{l^+}\rvert > \lvert\eta_{l^-}\rvert) - N(\lvert\eta_{l^+}\rvert < \lvert\eta_{l^-}\rvert)}{N(\lvert\eta_{l^+}\rvert > \lvert\eta_{l^-}\rvert) + N(\lvert\eta_{l^+}\rvert < \lvert\eta_{l^-}\rvert)}$	0.010	0.011	0.0007	-0.0005
$A_{topFB} = \frac{N(\cos(\theta_t) > 0) - N(\cos(\theta_t) < 0)}{N(\cos(\theta_t) > 0) + N(\cos(\theta_t) < 0)}$	-0.010	-0.017	-0.0067	0.0004

- Difference attributable to tau decays calculated by comparing to slide 3. Results compatible with results from reweighting powheg-pythia (slide 5).

powheg pythia vs tauola, parton level, no cuts

	powheg-pythia	powheg-tauola	difference	
$\mathcal{A}^{\ell\ell}_{\Delta\phi} = \frac{N(\cos\Delta\phi_{\ell\ell} > 0) - N(\cos\Delta\phi_{\ell\ell} < 0)}{N(\cos\Delta\phi_{\ell\ell} > 0) + N(\cos\Delta\phi_{\ell\ell} < 0)}$	-0.119	-0.117	0.0011	±0.0012
$\mathcal{P}_n^{+} = \frac{N(\cos\theta_{\ell,n} > 0) - N(\cos\theta_{\ell,n} < 0))}{N(\cos\theta_{\ell,n} > 0) + N(\cos\theta_{\ell,n} < 0))}$	0.003	0.004	0.0013	±0.0012
$\mathcal{P}_n^{-} = \frac{N(\cos\theta_{\ell,n} > 0) - N(\cos\theta_{\ell,n} < 0))}{N(\cos\theta_{\ell,n} > 0) + N(\cos\theta_{\ell,n} < 0))}$	0.003	0.003	0.0001	±0.0012
$\mathcal{A}^{\ell}_{c_1 c_2} = \frac{N(c_1 c_2 > 0) - N(c_1 c_2 < 0))}{N(c_1 c_2 > 0) + N(c_1 c_2 < 0))}$	-0.063	-0.062	0.0006	±0.0012
$A_{lepC} = \frac{N(\lvert\eta_{l^+}\rvert > \lvert\eta_{l^-}\rvert) - N(\lvert\eta_{l^+}\rvert < \lvert\eta_{l^-}\rvert)}{N(\lvert\eta_{l^+}\rvert > \lvert\eta_{l^-}\rvert) + N(\lvert\eta_{l^+}\rvert < \lvert\eta_{l^-}\rvert)}$	0.004	0.004	0.0002	±0.0012
$A_{topFB} = \frac{N(\cos(\theta_t) > 0) - N(\cos(\theta_t) < 0)}{N(\cos(\theta_t) > 0) + N(\cos(\theta_t) < 0)}$	0.005	0.005	0.0002	±0.0012

- As expected, the two MCs are statistically consistent at parton-level when no cuts are made (using status 3 taus)
- There must be other differences besides taus in the decay, but nothing obvious in config files:
  - http://cmssw.cvs.cern.ch/cgi-bin/cmssw.cgi/CMSSW/Configuration/GenProduction/python/POWHEG_PYTHIA6_ttbar_lnublnub_7TeV_cff.py?hideattic=0&revision=1.6&view=markup
  - http://cmssw.cvs.cern.ch/cgi-bin/cmssw.cgi/CMSSW/Configuration/GenProduction/python/POWHEG_PYTHIA6_top_tauola_cff.py?hideattic=0&revision=1.2&view=markup

Conclusions

- There is a significant systematic difference between the powheg-pythia and powheg-tauola samples for the polarisation measurement
- Only a small amount of the difference (~25%) is attributable to tau decays
  - what other difference between the two MCs could I be missing?
- May be OK to use MC@NLO for the paper?